



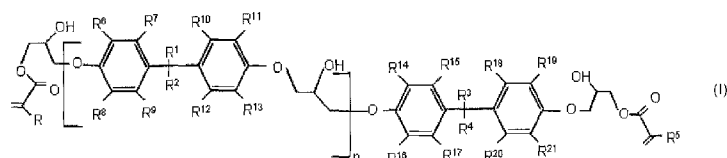
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(54) **Title:** WELLBORE STRENGTHENING COMPOSITION

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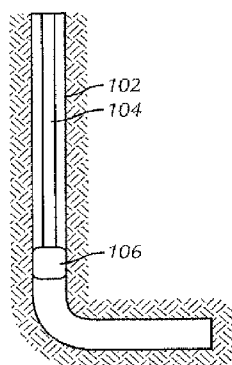


FIG. 4

(57) **Abstract:** In one aspect, embodiments disclosed herein relate to a wellbore strengthening composition including at least one polymer capable of polymerizing through a free radical polymerization reaction from the group of epoxy acrylates, modified epoxy acrylates, epoxy precursors, modified epoxy vinyl esters, unsaturated polyesters, urethane (meth)acrylates, polyester acrylates, epoxy vinyl ester resins having the formula (I) wherein R and R¹-R⁵ may be CH₃- or H and R⁶-R²¹ may be H or Br, and polymer combinations thereof; and at least one initiator, wherein the resin is present in the amount from about 10 to about 90 weight percent.

WELLBORE STRENGTHENING COMPOSITION

BACKGROUND

- [0001] Oilfield drilling typically occurs in geological formations having various compositions, permeabilities, porosities, pore fluids, and internal pressures. Weak zones may occur during drilling due to these formations having a variety of conditions. These weak zones may lead to fluid loss, pressure changes, well cave-ins, etc. The formation of weak zones is detrimental to drilling because they need to be strengthened before drilling work may resume.
- [0002] Weak zones may occur, for example, when the fracture initiation pressure of one formation is lower than the internal pore pressure of another formation. As another example, increased borehole pressure, created by penetrating one formation, may cause a lower strength formation to fracture. As another example, the fluid pressure gradient in a borehole required to contain formation pore pressure during drilling may exceed the fracture pressure of a weaker formation exposed in a borehole.
- [0003] Typically, weak zones have been strengthened by pumping a fluid into the weak zone, letting the fluid cure and develop strength over a period of time. Fluids used in the past include cement, epoxy resins with amine initiators and vinyl toluenes with initiators. The cure time for cement may be as long as 24 hours, delaying oil production which is undesirable, especially for off-shore drilling with high operating costs. Cement's particle based structure may also exhibit poor penetration capabilities in the formation leading to a reduced sealing effect. When using epoxy resins or vinyl toluenes, the cure time may be reduced, but the compositions are toxic, highly corrosive, flammable and pose a health hazard.
- [0004] Cement, or other fluid compositions used for strengthening weak zones, may also be used in primary cementing operations which fill at least a portion of the annular space between the casing and the formation wall with the fluid. The cement may then be allowed to solidify in the annular space, thereby forming an annular sheath of cement. The cement barrier is desirably impermeable, such that it will

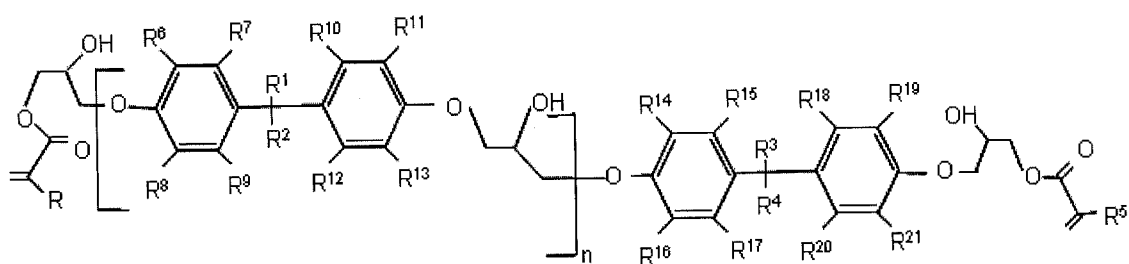
prevent the migration of fluid between zones or formations previously penetrated by the wellbore.

[0005] Typically, the cement or strengthening composition is mixed at the surface and pumped downhole at high pressure to fill in the weak zone. Once the composition fills in the weak zones, it is allowed to set or cure, harden within the well bore.

[0006] Accordingly, there exists a need to reduce the amount of time required for curing along with making a safe composition.

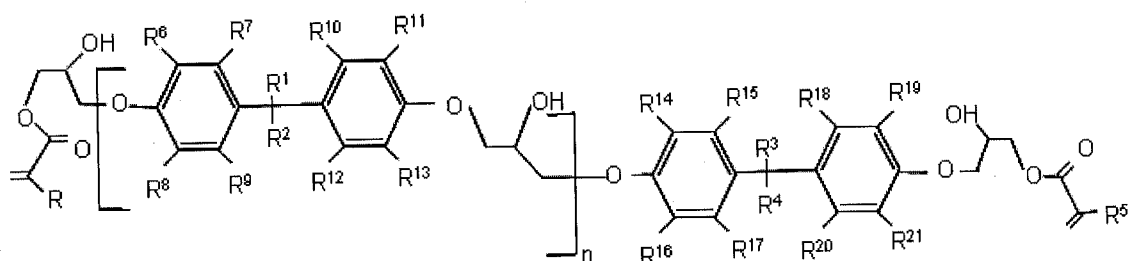
SUMMARY

[0007] In one aspect, embodiments disclosed herein relate to a wellbore strengthening composition including at least one polymer capable of polymerizing through a free radical polymerization reaction from the group of epoxy acrylates, modified epoxy acrylates, epoxy precursors, modified epoxy vinyl esters, unsaturated polyesters, urethane (meth)acrylates, polyester acrylates, epoxy vinyl ester resins having the formula:



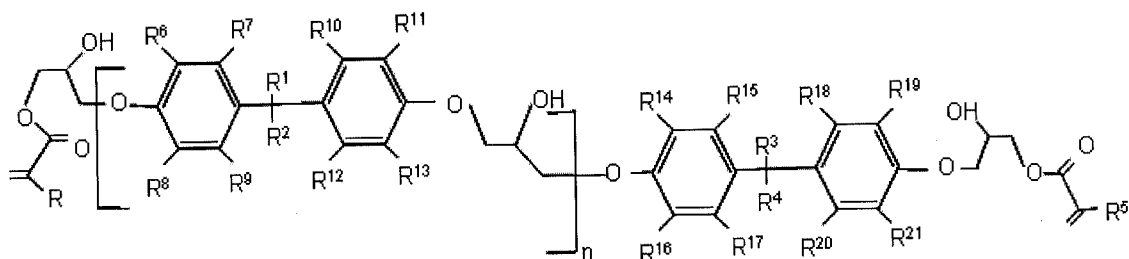
[0008] wherein R and R¹-R⁵ may be CH₃- or H and R⁶-R²¹ may be H or Br, and polymer combinations thereof; and at least one initiator, wherein the resin is present in the amount from about 10 to about 90 weight percent.

[0009] In another aspect, embodiments disclosed herein relate to a method of treating an earth formation including introducing at least one polymer in a liquid phase into the earthen formation; introducing at least one initiator into the earthen formation; and contacting the polymer and the initiator to form a composite; wherein the polymer comprises at least one polymer capable of polymerizing through a free radical polymerization reaction from the group of epoxy acrylates, modified epoxy acrylates, epoxy precursors, modified epoxy vinyl esters, unsaturated polyesters, urethane (meth)acrylates, polyester acrylates, epoxy vinyl ester resins having the formula:



[0010] wherein R and R¹-R⁵ may be CH₃- or H and R⁶-R²¹ may be H or Br, and polymer combinations thereof.

[0011] In another aspect, embodiments disclosed herein relate to method for sealing a subterranean well comprising: pumping at least one polymer in a liquid phase into at least a portion of an annular space between the sidewalls of a wellbore and the exterior of a casing string disposed in the wellbore, pumping at least one initiator into at least a portion of the annular space; and allowing the at least one polymer and the at least one initiator to solidify into a composite therein, wherein the at least one polymer comprises at least one polymer capable of polymerizing through a free radical polymerization reaction from the group of epoxy acrylates, modified epoxy acrylates, epoxy precursors, modified epoxy vinyl esters, unsaturated polyesters, urethane (meth)acrylates, polyester acrylates, epoxy vinyl ester resins having the formula:



[0012] wherein R and R¹-R⁵ may be CH₃- or H and R⁶-R²¹ may be H or Br, and polymer combinations thereof.

BRIEF DESCRIPTION OF THE FIGURES

[0013] Fig. 1 graphically compares curing temperatures and curing times for wellbore strengthening compositions according to embodiments disclosed herein.

[0014] Fig. 2 graphically compares torque and curing times for wellbore strengthening compositions according to embodiments disclosed herein.

[0015] Fig. 3 graphically compares torque and curing times for wellbore strengthening compositions according to embodiments disclosed herein.

[0016] FIG. 4 shows a schematic of a wellbore operation.

[0017] FIG. 5 shows a schematic of a wellbore operation.

[0018] FIG. 6 shows a schematic of a wellbore operation.

DETAILED DESCRIPTION

[0019] Embodiments disclosed herein relate to the use of wellbore strengthening compositions in downhole applications. Other embodiments of the disclosure relate to methods for producing wellbore strengthening compositions. In the following description, numerous details are set forth to provide an understanding of the present disclosure. However, it will be understood by those skilled in the art that the present invention may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0020] In one aspect, embodiments disclosed herein relate to a process for treating an earthen formation. The process may include: introducing a mixture of a polymer and an initiator into the earthen formation, and contacting the polymer and the initiator to form a composite. In other aspects, embodiments disclosed herein relate to methods of making such composites, and applications in which the composites disclosed herein may be useful.

[0021] Composite

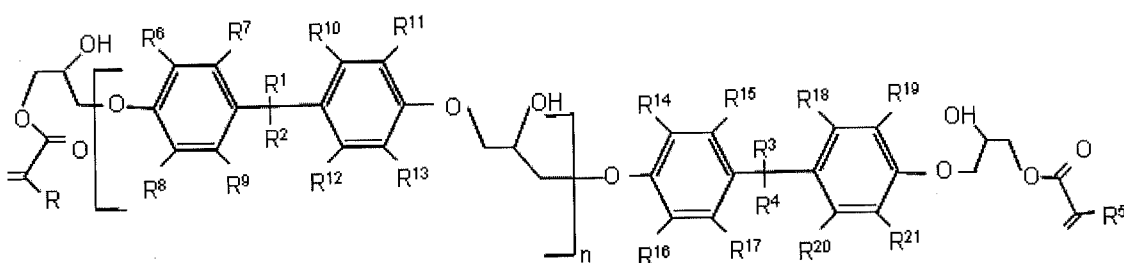
[0022] The composites of the present disclosure may be used in downhole applications as a component of drilling mud or they may be preformed and pumped downhole without drilling mud. Alternatively, the components may be introduced simultaneously or sequentially downhole forming the composite in situ. For example, the liquid components may be pumped into a wellbore which traverses a loosely consolidated formation, and allowed to cure, thereby forming a polymeric network which stabilizes the formation and the wellbore as a whole.

[0023] In some embodiments, the composites are formed from a variety of resins which are polymerized to form the composite structure. Further, accelerators or retardants may optionally be added to effect or enhance composite formation. Also, additives such as stabilizers, plasticizers, adhesion promoters, and fillers may be added to enhance or tailor the composite properties.

[0024] Curable polymers

[0025] Curable polymers (or pre-polymers) may be cured or cross-linked to a higher molecular weight bulk material, such as the composite of the present disclosure, which may have desirable mechanical and chemical properties. Such properties may include hardness, durability, and resistance to chemicals.

[0026] In some embodiments, a curable polymer may include an epoxy vinyl ester resin of the following formula:



[0027] wherein R and R¹ - R⁵ may be CH₃- or H and R⁶ - R²¹ may be H or Br. In other embodiments, the reactive polymer may be a vinyl ester polymer formed from the esterification of an epoxy resin with an unsaturated carboxylic acid, modified epoxy acrylates, modified epoxy vinyl esters, unsaturated polyesters, or combinations thereof. The epoxy resin may be formed from bisphenol a type, bisphenol f type, novolac, and aliphatic epoxies. Related derivatives may also be used as long as they

are polymerizable through a free radical polymerization reaction. As used herein, modified means hybrid polymers or polymers that are extended with other molecules that are not bisphenol derivatives.

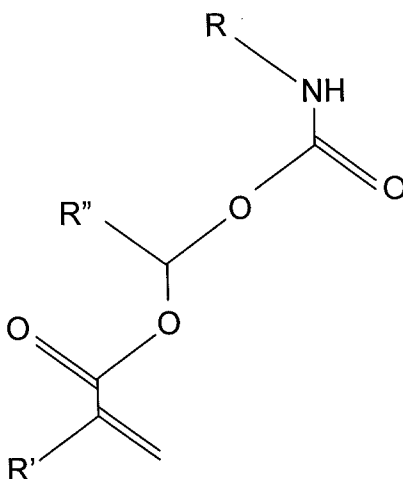
[0028] Depending on the particular application, it may be desirable to form a composite to treat weak or permeable formations. Liquid polymer solutions are particularly well suited for downhole applications because they are pumpable in their uncured state. In various embodiments, the liquid polymer solutions may be used in its neat form, may be dissolved in a solvent, or may be dispersed or emulsified in a non-miscible phase, and a curing agent may be added to the liquid solution to form a composite.

[0029] For example, such a liquid polymer solution may be pumped downhole to traverse a loosely consolidated formation in the wellbore. An initiator and desired additives may then be pumped downhole to initiate curing of the liquid polymer solution to form a strongly bonded matrix that may efficiently coat the loosely consolidated formation. The inventors of the present disclosure have discovered that such a strongly bonded matrix may effectively retain the loosely consolidated formation, therefore controlling the production of sand grains from the treated zones. This treatment may serve to strengthen the wellbore and reduce debris which may cause wear to downhole tools.

[0030] The curable polymer may be used in an amount ranging from about 10 to about 90 weight percent, based on the total weight of the composite, from about 20 to about 80 weight percent in other embodiments, and from about 30 to about 70 weight percent in yet other embodiments.

[0031] In some embodiments, the curable polymer may be a combination of a first polymer of at least one epoxy vinyl ester resin having the formula described above and a second polymer of at least one polymer capable of polymerizing through a free radical polymerization reaction from the group of epoxy acrylates, modified epoxy acrylates, epoxy precursors, modified epoxy vinyl esters, unsaturated polyesters, urethane acrylates, urethane (meth)acrylates, polyester acrylates or combinations thereof.

[0032] In some embodiments, an epoxy vinyl ester may be used in combination with a urethane acrylate resin of the following formula:



[0033] wherein R may be an aliphatic or aromatic group, such as a C6-C28 aliphatic or aromatic group and in which additional functionalization and/or substitution may be included and wherein R' or R'' may be hydrogen or methyl. The urethane acrylate may be derived from hydroxyl functional (meth) acrylate and an isocyanate. Advantageously, embodiments using a combination of the first and second polymers (such as the vinyl ester and urethane acrylate in a particular embodiment) may allow for a low exothermic reaction, which may be defined as a release of only 10 to 40 degrees F during the polymerization.

[0034] The first polymer may be used in an amount ranging from about 0 to about 100 weight percent, based on the total weight of the curable polymer, from about 10 to about 90 weight percent in other embodiments, and from about 20 to about 80 weight percent in yet other embodiments. The second polymer may be used in an amount ranging from about 0 to about 100 weight percent, based on the total weight of the curable polymer, from about 10 to about 90 weight percent in other embodiments, and from about 20 to about 80 weight percent in yet other embodiments.

[0035] Diluent

[0036] The polymer may be combined with a reactive diluent. The reactive diluent may be a monomer or blend of monomers that are polymerizable by free-radicals. Examples of such monomers include the following: vinyl monomers such as styrene derivatives (styrene, vinyl toluene, alpha methyl styrene, divinyl benzene, tertiary butyl styrene, diallyl phthalate, isocyanurate and others); acrylates and methacrylates (monofunctional, multifunctional, hydroxyl functionalized, amine functionalized, carboxylic acid functional, polyether polyol extended, all esters of acrylic acid or methacrylic acid, and others); vinyl ester monomers (esters of versatic acid such as VeoVa™ 10 by Hexion Specialty Chemicals, Columbus, OH); and combinations thereof, as well as all related derivatives that are cross-linkable through a free radical polymerization reaction.

[0037] Some examples of acrylates and methacrylates include: hydroxyethyl methacrylate (HEMA), hydroxypropyl methacrylate (HPMA), acrylic acid, methacrylic acid, methyl acrylate, ethyl acrylate, propyl acrylate, butyl acrylate, isodecyl acrylate, stearyl acrylate, lauryl acrylate, tridecyl acrylate, isoctyl acrylate, ethoxylated bisphenol A diacrylate, ethoxylated hydroxyethyl acrylate, allyl acrylate, glycidyl methacrylate, 1,4-butanediol diacrylate (BDDA), 1,6-hexanediol diacrylate (HDDA), diethylene glycol diacrylate, 1,3-butylene glycol diacrylate, neopentyl glycol diacrylate, cyclohexane dimethanol diacrylate, dipropylene glycol diacrylate, ethoxylated bisphenol A diacrylate, trimethylolpropane triacrylate, pentaerythritol triacrylate, pentaerythritol tetraacrylate, polyethylene glycol diacrylate, polypropylene glycol diacrylate, 4-acryloylmorpholine, metal chelated derivatives of acrylates, and all related derivatives and all methacrylate and acrylate derivatives thereof.

[0038] The reactive diluent may be used in an amount ranging from about 10 to about 90 weight percent, based on the total weight of the composite, from about 20 to about 80 weight percent in other embodiments, and from about 30 to about 70 weight percent in yet other embodiments.

[0039] Initiator

[0040] In one embodiment, the polymers and/or monomers are contacted with at least one initiator in order to effect the formation of the composite. In general, the initiator

may be any nucleophilic or electrophilic group that may react with the reactive groups available in the polymers and/or monomers. In a further embodiment, the initiator may comprise a polyfunctional molecule with more than one reactive group. Such reactive groups may include for example, amines, alcohols, phenols, thiols, carbanions, organofunctional silanes, and carboxylates.

[0041] Examples of initiators include free radical initiating catalysts, azo compounds, alkyl or acyl peroxides or hydroperoxides, dialkyl peroxides, ketoperoxides, peroxy esters, peroxy carbonates, peroxy ketals, and combinations thereof. Examples of free radical initiating catalysts include benzoyl peroxide, dibenzoyl peroxide, diacetyl peroxide, di-t-butyl peroxide, cumyl peroxide, dicumyl peroxide, dilauryl peroxide, t-butyl hydroperoxide, methyl ketone peroxide, acetylacetone peroxide, methylethyl ketone peroxide, dibutylperoxyl cyclohexane, di (2,4-dichlorobenzoyl) peroxide, diisobutyl peroxide, t-butyl perbenzoate, t-butyl peracetate, and combinations thereof.

[0042] In some embodiments, the initiators may be peroxide based and/or persulfates. The amount of initiators is preferably from about 0.1 wt% to about 3 wt%, more preferably from about 0.7 wt% to about 1 wt%, most preferably from about 0.3 wt% to about 0.5 wt%.

[0043] Accelerators and Retardants

[0044] Accelerators and retardants may optionally be used to control the cure time of the composite. For example, an accelerator may be used to shorten the cure time while a retardant may be used to prolong the cure time. In some embodiments, the accelerator may include an amine, a sulfonamide, or a disulfide, and the retardant may include a stearate, an organic carbamate and salts thereof, a lactone, or a stearic acid.

[0045] Additives

[0046] Additives are widely used in polymeric composites to tailor the physical properties of the resultant composite. In some embodiments, additives may include plasticizers, thermal and light stabilizers, flame-retardants, fillers, adhesion promoters, or rheological additives.

[0047] Addition of plasticizers may reduce the modulus of the polymer at the use temperature by lowering its glass transition temperature (T_g). This may allow control

of the viscosity and mechanical properties of the composite. In some embodiments, the plasticizer may include phthalates, epoxides, aliphatic diesters, phosphates, sulfonamides, glycols, polyethers, trimellitates or chlorinated paraffin. In some embodiments, the plasticizer may be a diisooctyl phthalate, epoxidized soybean oil, di-2-ethylhexyl adipate, tricresyl phosphate, or trioctyl trimellitate.

[0048] Fillers are usually inert materials which may reinforce the composite or serve as an extender. Fillers therefore affect composite processing, storage, and curing. Fillers may also affect the properties of the composite such as electrical and heat insulating properties, modulus, tensile or tear strength, abrasion resistance and fatigue strength. In some embodiments, the fillers may include carbonates, metal oxides, clays, silicas, mica, metal sulfates, metal chromates, or carbon black. In some embodiments, the filler may include titanium dioxide, calcium carbonate, non-acidic clays, barium sulfate or fumed silica. The particle size of the filler may be engineered to optimize particle packing, providing a composite having reduced resin content. The engineered particle size may be a combination of fine, medium and coarse particles. The particle size may range from about 3 to about 74 microns.

[0049] Addition of adhesion promoters may improve adhesion to various substrates. In some embodiments, adhesion promoters may include modified phenolic resins, modified hydrocarbon resins, polysiloxanes, silanes, or primers.

[0050] Addition of rheological additives may control the flow behavior of the compound. In some embodiments, rheological additives may include fine particle size fillers, organic agents, or combinations of both. In some embodiments, rheological additives may include precipitated calcium carbonates, non-acidic clays, fumed silicas, or modified castor oils.

[0051] Composite Preparation

[0052] In one embodiment, the composite is formed by mixing the polymer, and optionally the diluent, with the initiators and additives. In some embodiments, appropriate solvents may also be included. Solvents that may be appropriate may comprise oil-based muds for use in downhole applications and may include mineral oil, biological oil, diesel oil, and synthetic oils.

[0053] Aging Temperature

[0054] In some embodiments, the curable polymer and the initiator may be reacted at a temperature ranging from about 25 to about 250°C; from about 50 to about 150°C in other embodiments; and from about 60 to about 100°C in yet other embodiments. In other embodiments, the curable polymer and the initiator may be reacted at a temperature of about 65°C. However, one of ordinary skill in the art would appreciate that, in various embodiments, the reaction temperature may determine the amount of time required for composite formation.

[0055] Time Required for Composite Formation

[0056] Embodiments of the composites disclosed herein may be formed by mixing a curable polymer with an initiator. In some embodiments, a composite may form within about 3 hours of mixing the polymer and the initiator. In other embodiments, a composite may form between about 4 to about 6 hours of mixing the polymer and the initiator; between about 7 to about 9 hours of mixing in other embodiments.

[0057] The initiator upon aging at temperatures of about 80 °F to about 250 °F prompts the formation of free radicals in the polymers and/or diluent monomers. The radicals in turn cause the bond formation of the polymers and/or diluent monomers. The bonding changes the liquid composition into a hard composite.

[0058] The wellbore strengthening composition may also contain other common treatment fluid ingredients such as fluid loss control additives, dyes, anti-foaming agents when necessary, and the like, employed in typical quantities, known to those skilled in the art. Of course, the addition of such other additives should be avoided if it will detrimentally affect the basic desired properties of the treatment fluid.

[0059] Embodiments of the composite materials disclosed herein may possess greater flexibility in their use in wellbore and oilfield applications, as compared to conventional cement. For example, the composite material may be used in applications including: primary cementing operations, zonal isolation; loss circulation; wellbore (WB) strengthening treatments; reservoir applications such as in controlling the permeability of the formation, etc. Depending on the particular application, a resin formulation of the present disclosure may be directly emplaced

into the wellbore by conventional means known in the art into the region of the wellbore in which the resin formulation is desired to cure or set into the composite. Alternatively, the resin formulation may be emplaced into a wellbore and then displaced into the region of the wellbore in which the resin formulation is desired to set or cure.

[0060] According to various embodiments, the formulations of the present disclosure may be used where a casing string or another liner is to be sealed and/or bonded in the annular space between the walls of the borehole and the outer diameter of the casing or liner with composite material of the present disclosure. For example, following drilling of a given interval, once placement of a casing or liner is desired, the drilling fluid may be displaced by a displacement fluid. The drill bit and drill string may be pulled from the well and a casing or liner string may be suspended therein. The present formulation of components may be pumped through the interior of the casing or liner, and following the present fluid formulation, a second displacement fluid (for example, the fluid with which the next interval will be drilled or a fluid similar to the first displacement fluid) may displace the present fluid into the annulus between the casing or liner and borehole wall. Once the composite material has cured and set in the annular space, drilling of the next interval may continue. Prior to production, the interior of the casing or liner may be cleaned and perforated, as known in the art of completing a wellbore. Alternatively, the formulations may be pumped into a selected region of the wellbore needing consolidation, strengthening, etc., and following curing, a central bore may be drilled out.

[0061] Further, in embodiments, a casing may be run into the hole having a fluid therein, followed by pumping a sequence of a spacer fluid ahead of a resin formulation according to the present disclosure, after which a displacement fluid may displace the formulation into the annulus. Further embodiments may use both a cementitious slurry and a resin formulation (pumped in either order, cement then resin or resin then cement) and/or multiple volumes of cement and resin, such as cement-resin-cement or resin-cement-resin, with appropriate placement of spacers and/or wiper plugs. When using both cement and a resin formulation, different setting

times between the cement and resin formulation may be used so that the resin may be set in compression or the resin may be set while the cement is still fluid.

[0062] Wellbore stability may also be enhanced by the injection of the resin formulation into formations along the wellbore. The mixture may then react or continue to react, strengthening the formation along the wellbore upon polymerization of the curable polymer and reactive diluent.

[0063] Embodiments of the gels disclosed herein may be used to enhance secondary oil recovery efforts. In secondary oil recovery, it is common to use an injection well to inject a treatment fluid, such as water or brine, downhole into an oil-producing formation to force oil toward a production well. Thief zones and other permeable strata may allow a high percentage of the injected fluid to pass through only a small percentage of the volume of the reservoir, for example, and may thus require an excessive amount of treatment fluid to displace a high percentage of crude oil from a reservoir.

[0064] To combat the thief zones or high permeability zones of a formation, embodiments of the resin formulations disclosed herein may be injected into the formation. The resin formulation injected into the formation may react and partially or wholly restrict flow through the highly conductive zones. In this manner, the composite may effectively reduce channeling routes through the formation, forcing the treating fluid through less porous zones, and potentially decreasing the quantity of treating fluid required and increasing the oil recovery from the reservoir.

[0065] In other embodiments, the composites of the present disclosure may be formed within the formation to combat the thief zones. The resin formulation may be injected into the formation, allowing the components to penetrate further into the formation than if a gel was injected. By forming the composites in situ in the formation, it may be possible to avert channeling that may have otherwise occurred further into the formation, such as where the treatment fluid traverses back to the thief zone soon after bypassing the injected gels as described above.

[0066] As another example, embodiments of the resin formulation disclosed herein may be used as a loss circulation material (LCM) treatment when excessive seepage or circulation loss problems are encountered. In such an instance, the resin formulation may be emplaced into the wellbore into the region where excessive fluid

loss is occurring and allowed to set. Upon setting, the composite material may optionally be drilled through to continue drilling of the wellbore to total depth.

[0067] In some embodiments, the curable polymer, reactive diluents, and initiator may be mixed prior to injection of the formulation into the drilled formation. The mixture may be injected while maintaining a low viscosity, prior to polymerization formation, such that the composite may be formed downhole. In other embodiments, one or more of the components, such as the initiator, may be injected into the formation in separate shots, mixing and reacting to form a composite in situ. In this manner, premature reaction may be avoided. For example, a first mixture containing curable polymer and/or reactive diluent may be injected into the wellbore and into the lost circulation zone. A second mixture containing an initiator (and optionally, one of the curable polymer and/or reactive diluents) may be injected, causing the curable polymer and reactive diluent to crosslink in situ. The hardened composite may plug fissures and thief zones, closing off the lost circulation zone.

[0068] Methods of the present application may isolate pressures between metal tubulars using the composite materials of the present application. For example, in drilling and completion applications, mechanical isolation devices may be used to partition the well. A mechanical packer (containing a sealing element of metal and/or elastomer) may be placed in a well and once set in place, will provide pressure isolation to a tested rating, such as to separate producing and non-producing intervals in a completion.

[0069] A slurry of the present disclosure may be placed in a wellbore through pumping or settling and solidify, isolating a pressure zone. Once hardened, the material may have some flexibility but adheres to the metal tubulars within the wellbore, providing pressure isolation.

[0070] In well suspensions, this may provide a temporary barrier within casing. In completion operations, this barrier may be placed between an outer casing and an inner tubing to isolate pressure. One application may include placing the slurry on top of a conventionally set packer for additional reliability or as a repair mechanism. Completion tubing is capable of flexing with changing in temperature and the ability of this material to adhere yet be flexible without fracturing. This may provide zonal

isolation typically only provided through elastomer seals which may not be pumped downhole.

[0071] In another embodiment, the composite material may be used as a well remediation application where the slurry is placed in between two concentric casing strings to act as a pressure barrier. For example, this may take place when a casing cement does not sufficiently isolate pressurized zones, allowing fluid to pass between the casing strings. The slurry material of the present application may be pumped or placed in the space behind the cement to seal behind the leaking space.

[0072] Referring to FIG. 4, use of the composite materials of the present disclosure as an isolation barrier for well suspension is shown. As shown in FIG. 4, a suspension material 106 (*i.e.*, the slurry of the present disclosure) is pumped into wellbore in which a drill pipe 104 is located. Upon consolidation, the suspension material 106 may adhere to casing 102 and solidify to create a barrier.

[0073] Referring now to FIG. 5, use of the composite materials of the present disclosure as a repair/secondary seal for a leaking mechanical packer is shown. As shown in FIG. 5, a packer 208 isolates two regions of wellbore 202, the producing region and non-producing region. Production tubing 204 ends in the lower, producing region of the well to produce therefrom. If the packer 208 begins to leak fluid therethrough, a slurry of the present disclosure may be placed above the packer 208 and allowed to solidify between casing / wellbore 202 and the production tubing 204 to isolate the lower region from the upper region and provide a backup/secondary seal to the leaking packer.

[0074] Referring now to FIG. 6, use of the composite materials of the present disclosure as an annular mechanical barrier is shown. Specifically, as shown in FIG. 6, if there is improper isolation between a first outer casing 302 and a second inner casing 304, fluid may flow (shown at 308) between first and second casings 302, 304. Thus, placement of a composite material of the present disclosure between first and second casings 302, 304, may allow for the isolation of pressure and formation of a mechanical barrier.

[0075]

[0076] EXAMPLES

[0077] Samples of F010 Vipel[®] Bisphenol A epoxy vinyl ester resins available from AOC Resins (Collierville, TN), Barite (API grade barium sulfate), Crayvallac[™] SL (or PC?) a polyamide based viscosifier available from Cook Composite and Polymers (Kansas City, MO), and benzoyl peroxide (40 wt% blend in dibutyl phthalate) from Sigma Aldrich (St. Louis, Mo) were mixed in various proportions. Mixing was done at about room temperature. The Vipel[®] F010 contains styrene monomer to dilute the epoxy vinyl ester polymer.

Table 1

Example	1	2	3
Vipel [®] F010(g)	100	50	50
Barite (g)	48	50	50
Crayvallac [™] SL (g)	2.8	0.8	0.8
Benzoyl Peroxide (g)	0.5	0.5	0.5
Curing Temperature (°F)	150	150	150
Curing Time (hour)	3-4	3-4	3-4
Result	Hard composite	Hard composite	Hard composite

[0078] Samples of XR 3129 epoxy vinyl ester resins available from AOC Resins (Collierville, TN), VeoVa[™] 10 (vinyl ester of VERSATIC[™] Acid 10 a synthetic saturated monocarboxylic acid with a highly branched structure containing ten carbon atoms) available from Hexion Specialty Chemicals (Columbus, OH) were mixed in various proportions with Trigonox K-90 cumyl hydroperoxide available from AkzoNobel (Norcross, GA). Mixing was done at room temperature and aging was done at a temperature of about 150 °F.

Table 2

Example	4	5	6	7	8
XR 3129 (g)	40	30	50	50	50
VeoVa [™] 10 (g)	10	20	0	10	10
Trigonox K-90 (g)	0.5	0.5	0.5	0.5	0.5
Curing Temperature (°F)	150	150	150	150	150
Curing Time (hour)	2-3	2-3	2-3	2-3	2-3
Result	Hard composite	Hard composite	Hard composite	Hard composite	Hard composite

[0079] Samples of XR 3129-L epoxy vinyl ester resins available from AOC Resins (Collierville, TN), VeoVa™ 10 (vinyl ester of VERSATIC™ Acid 10 a synthetic saturated monocarboxylic acid with a highly branched structure containing ten carbon atoms) available from Hexion Specialty Chemicals (Columbus, OH), Arcosolv® TPNB (Tripropylene Glycol Normal Butyl Ether) available from LyondellBasell (Houston, TX), Barite (API grade barium sulfate), and Rheliant™ synthetic drilling mud (14ppg) available from M-I LLC (Houston, TX) were mixed in various proportions with Trigonox K-90 cumyl hydroperoxide available from AkzoNobel (Norcross, GA). Mixing was done at room temperature and aging was done at a temperature of about 150 °F.

Table 3

Example	9	10	11	12	13
XR 3129-L (g)	45	40	42.5	42.5	42.5
VeoVa™ 10 (g)	5	10	5	5	5
Arcosolv® TPNB(g)	0	0	2.5	2.5	2.5
Barite (g)	50	50	50	50	50
Rheliant Mud (g)	65	65	65	65	65
Trigonox K-90 (g)	1	1	1	1	1
Curing Temperature (°F)	150	150	150	150	150
Curing Time (hour)	2-3	2-3	2-3	2-3	2-3
Result	Hard composite	Hard composite	Hard composite	Hard composite	Hard composite

[0080] Samples of XR 3146 epoxy vinyl ester resins available from AOC Resins (Collierville, TN), Barite (API grade barium sulfate), Crayvallac™ SL (or PC?) a polyamide based viscosifier available from Cook Composite and Polymers (Kansas City, MO), and benzoyl peroxide (40 wt% blend in dibutyl phthalate) from Sigma Aldrich (St. Louis, Mo) were mixed in various proportions. Mixing was done at room temperature and aging was done at a temperature of about 150 °F.

Table 4

Example	14	15
XR 3146(g)	50	50
Barite (g)	50	50
Crayvallac™ SL (g)	0	0.8
Benzoyl Peroxide (g)	0.5	0.5
Curing Temperature (°F)	150	150
Curing Time (hour)	3-4	3-4
Result	Hard composite	Hard composite

[0081] Samples of XR 3146 epoxy vinyl ester resins available from AOC Resins (Collierville, TN), Barite (API grade barium sulfate), Crayvallac™ SL (or PC?) a polyamide based viscosifier available from Cook Composite and Polymers (Kansas City, MO), benzoyl peroxide (40 wt% blend in dibutyl phthalate) from Sigma Aldrich (St. Louis, Mo), and Rheliant™ synthetic drilling mud (14ppg) available from M-I LLC (Houston, TX) were mixed in various proportions. Mixing was done at room temperature and aging was done at a temperature of about 150 °F.

Table 5

Example	16	17	18
XR 3146(g)	50	50	50
Barite (g)	50	50	50
Crayvallac SL (g)	0	0.8	0.8
Benzoyl Peroxide (g)	0.5	0.5	0.5
Rheliant Mud (ml)	6	15	20
% mud by volume	10	25	32
Curing Temperature (°F)	150	150	150
Curing Time (hour)	3-4	3-4	3-4
Result	Hard composite	Hard composite	Hard composite

[0082] Samples of XR 3146 epoxy vinyl ester resins available from AOC Resins (Collierville, TN), Barite (EMI 1012 UF barium sulfate) available from M-I LLC (Houston, TX), benzoyl peroxide (40 wt% blend in dibuty phthalate) from Sigma Aldrich (St. Louis, Mo), and Rheliant™ synthetic drilling mud (14ppg) available from M-I LLC (Houston, TX) were mixed in various proportions. Mixing was done at room temperature and aging was done at a temperature of about 150 °F.

Table 6

Example	19	20	21	22
XR 3146(g)	50	50	50	50
Barite (g)	24	24	24	0
Benzoyl Peroxide (g)	0.35	0.5	1.25	1
Rheliant Mud (g)	0	24	24	0
Curing Temperature (°F)	150	150	150	150
Curing Time (hour)	3-4	3-4	3-4	3-4
Result	Hard composite	Hard composite	Hard composite	Hard composite

[0083] Samples of XR 3191 epoxy vinyl ester resins available from AOC Resins (Collierville, TN), Barite (EMI 1012 UF barium sulfate) available from M-I LLC

(Houston, TX), benzoyl peroxide (40 wt% blend in dibutyl phthalate) from Sigma Aldrich (St. Louis, Mo), and Rheliant™ synthetic drilling mud (14ppg) available from M-I LLC (Houston, TX) were mixed in various proportions. Mixing was done at room temperature and aging was done at a temperature of about 150 °F.

Table 7

Example	19	20
XR 3191(g)	50	50
Barite (g)	24	24
Benzoyl Peroxide (g)	0.75	0.75
Rheliant Mud (g)	8.65	26
% mud by volume	10	30
Curing Temperature (°F)	150	150
Curing Time (hour)	2-3	2-3
Result	Hard composite	Hard composite

[0084] Samples of XR 3191 epoxy vinyl ester resins available from AOC Resins (Collierville, TN), Barite (EMI 1012 UF barium sulfate) available from M-I LLC (Houston, TX), benzoyl peroxide (40 wt% blend in dibuty phthalate) from Sigma Aldrich (St. Louis, Mo), and Rheliant™ synthetic drilling mud (11.31 ppg) available from M-I LLC (Houston, TX) were mixed in various proportions. Mixing was done at room temperature and aging was done at a temperature of about 150 °F.

Table 8

Example	21	22	23
XR 3191(g)	200	200	200
Barite (g)	132	132	132
Benzoyl Peroxide (g)	0.86	0.96	0.96
Rheliant Mud (g)	0	30	60
Curing Temperature (°F)	150	150	150
Curing Time (hour)	4-6	4-6	4-6
Result	Hard composite	Hard composite	Hard composite
Unconfined Compressive Strength (psi)	7140	1980	566

[0085] The XR series of epoxy vinyl ester resins do not contain styrene as a diluent, thereby reducing the toxicity of the composition. Compositions made with XR 3129 produced a higher viscosity product than those compositions made with XR 3129L, XR 3146, or XR 3191. XR 3146 provides a composition with high unconfined

compressive strength. XR 3191 provides for using various concentrations of activator while still providing a composition having good strength.

[0086] Samples of A057-BBB-000 epoxy vinyl ester/urethane acrylate resins available from AOC Resins (Collierville, TN), HiSil™ 532 EP (silica powder) available from PPG Industries (Monroeville, PA), Barite (1012 UF barium sulfate) available from M-I LLC (Houston, TX), PBQ (parabenzquinone solution 50 mg in 2 g), Trigonox 42 S tert-butyl peroxy-3,5,5-trimethylhexanoate available from AkzoNobel (Norcross, GA), benzoyl peroxide (40 wt% blend in dibutyl phthalate) from Sigma Aldrich (St. Louis, Mo), Rheliant™ synthetic drilling mud (12 ppg) available from M-I LLC (Houston, TX), and Cement H (as a cement contaminant) were mixed in various proportions. Mixing was done at room temperature and aging was done at a temperature of about 150 °F. A time versus temperature graph for Examples 24 and 24 is shown in Figure 1.

Table 9

Example	24	25
A057-BBB-000 (g)	200	200
HiSil™ 532 EP (g)	4	4
Barite (g)	148	148
PBQ (g)	4	4
Trigonox 42 S (g)	0.28	0.28
Benzoyl Peroxide (g)	1.8	1.8
Rheliant Mud (g)	3.7	3.7
Cement H (g)	0	36
Curing Temperature (°F)	150	150
Result	Hard composite	Hard composite

[0087] Samples of A057-BBB-000 epoxy vinyl ester/urethane acrylate resins available from AOC Resins (Collierville, TN), HiSil™ 532 EP (silica powder) available from PPG Industries (Monroeville, PA), Barite (EMI 1012 UF barium sulfate) available from M-I LLC (Houston, TX), PBQ (2 % parabenzquinone solution in dipropylene glycol methyl ether), Trigonox 42 S tert-butyl peroxy-3,5,5-trimethylhexanoate available from AkzoNobel (Norcross, GA), benzoyl peroxide (40 wt% blend in dibutyl phthalate) from Sigma Aldrich (St. Louis, Mo), were mixed in various proportions. Mixing was done at room temperature and aging was done at a temperature of about 170 °F.

Table 10

Example	26	27
A057-BBB-000 (g)	300	150
HiSil™ 532 EP (g)	4.5	10
Barite (g)	251.58	17.25
PBQ (g)	6	1.25
Trigonox 42 S (g)	0.42	0.25
Benzoyl Peroxide (g)	2.7	1.4
Curing Temperature (°F)	170	170
Result	Hard composite	Hard composite
Time of composite formation (hours)	4-6	6-8
Weight of formulation (ppg)	12.5	9

[0088] A sample of A057-BBB-000 epoxy vinyl ester/urethane acrylate resins available from AOC Resins (Collierville, TN), HiSil™ 532 EP (silica powder) available from PPG Industries (Monroeville, PA), Barite (1012 UF barium sulfate) available from M-I LLC (Houston, TX), PBQ (2 % parabenzoquinone solution in diproylene glycol methyl ether), Trigonox 42 S tert-butyl peroxy-3,5,5-trimethylhexanoate available from AkzoNobel (Norcross, GA), Rheliant™ synthetic drilling mud (12 ppg) available from M-I LLC (Houston, TX) (to show effect of drilling fluid contamination), benzoyl peroxide (40 wt% blend in dibutyl phthalate) from Sigma Aldrich (St. Louis, Mo) and an activator were mixed in various proportions. Mixing was done at room temperature and aging was done at a temperature of about 150 °F.

Table 11

Example	28
A057-BBB-000 (g)	500
HiSil™ 532 EP (g)	10
Barite (g)	370
PBQ (g)	10
Trigonox 42 S (g)	0.68
Benzoyl Peroxide (g)	4.5
Rheliant Mud (g)	9.25
Activator	0.5%
Curing Temperature (°F)	150
Result	Hard composite

[0089] A sample of A057-BBB-000 epoxy vinyl ester/urethane acrylate resins available from AOC Resins (Collierville, TN), HiSil™ 532 EP (silica powder) available from PPG Industries (Monroeville, PA), Barite (1012 UF barium sulfate) available from M-I LLC (Houston, TX), Biscomer PTE (5 % N,N-Bis-(2-hydroxyethyl)-Para-toluidine solution) available from Cognis (Monheim, Germany), Trigonox 42 S tert-butyl peroxy-3,5,5-trimethylhexanoate available from AkzoNobel (Norcross, GA), Rheliant™ synthetic drilling mud (9 ppg) available from M-I LLC (Houston, TX) (as a drilling fluid contaminant), benzoyl peroxide (40 wt% blend in dibutyl phthalate) from Sigma Aldrich (St. Louis, Mo), were mixed in various proportions, as shown in Table 12. Mixing was done at room temperature and aging was done at a temperature of about 112 °F. Figure 2 shows the setting of the composite 29 with time.

Table 12

Example	29
A057-BBB-000 (g)	200
HiSil™ 532 EP (g)	8
Barite (g)	23
Biscomer PTE (g)	0.25
Trigonox 42 S (g)	2
Benzoyl Peroxide (g)	2.5
Rheliant Mud (g)	2.4
Curing Temperature (°F)	112
Result	Hard composite

[0090] A sample of A057-BBB-000 epoxy vinyl ester/urethane acrylate resins available from AOC Resins (Collierville, TN), HiSil™ 532 EP (silica powder) available from PPG Industries (Monroeville, PA), Barite (1012 UF barium sulfate) available from M-I LLC (Houston, TX), Cobalt 2-Ethylhexonate (12 % solution), Biscomer PTE (5 % N,N-Bis-(2-hydroxyethyl)-Para-toluidine solution) available from Cognis (Monheim, Germany), Trigonox 42 S tert-butyl peroxy-3,5,5-trimethylhexanoate available from AkzoNobel (Norcross, GA), Rheliant™ synthetic drilling mud (9 ppg) available from M-I LLC (Houston, TX), benzoyl peroxide (40 wt% blend in dibutyl phthalate) from Sigma Aldrich (St. Louis, Mo), and an activator were mixed in various proportions. Mixing was done at room temperature and aging

was done at a temperature of about 90 °F. Figure 3 shows the setting of the composite 30 with time.

Table 13

Example	30
A057-BBB-000 (g)	100
HiSil™ 532 EP (g)	4
Barite (g)	11.5
Cobalt -2 Ethylhexonate (g)	0.15
Biscomer PTE (g)	0.25
Trigonox 42 S (g)	1
Benzoyl Peroxide (g)	1.25
Rheliant Mud (g)	1.2
Activator	1.5%
Curing Temperature (°F)	90
Result	Hard composite

[0091] Applications

[0092] Some embodiments of the composites disclosed herein may be formed in a one-solution single component system, where the initiator is premixed with the curable polymers, and the mixture may then be placed or injected prior to cure. The cure times may be adjusted by changing the quantity of diluent (or other solvent) in the solution. The cure times may also be adjusted by changing the initiator and/or concentration of the initiator. Other embodiments of the composites disclosed herein may also be formed in a two-component system, where the initiators and curable polymers may be mixed separately and combined immediately prior to injection. Alternatively, one reagent, the polymers or initiator, may be placed in the wellbore or the near-wellbore region where it may then be contacted by the other reagent, either the polymers or initiator as required.

[0093] According to one embodiment of the present invention, at least a portion of the annular region between the metal casing in the borehole and the sidewall of the formation drilled may include a layer of solidified wellbore fluid. The solidified wellbore fluid may be formed by allowing a wellbore fluid including a curable polymer and at least one initiator, both of which are described above, to set within the annular space.

[0094] According to one embodiment of the present invention, a subterranean zone may be sealed by preparing a wellbore fluid that includes a curable polymer and at least one initiator, both of which are described above. The wellbore fluid may be placed in at least a portion of the annular space between the sidewalls of a wellbore and the exterior of a casing string disposed in the wellbore. The wellbore fluid may then be allowed to solidify therein. In some embodiments, a cement slurry may also be placed in at least a portion of the annular space between the sidewalls of the wellbore and the exterior of the casing string. The cement slurry may be placed in the annular space either with, before, or after the wellbore fluid is placed in the annular space. In other embodiments, at least a portion of the annular space is occupied with a pre-solidified or partially solidified cement barrier prior to the treated wellbore fluid being placed in the annular space. In some embodiments, the pumping of the wellbore fluid and the cement slurry occurs by pumping the wellbore fluid and the cement slurry through the casing string to fill the annular space.

[0095] Advantages of the current disclosure may include a composite with excellent ability to vary the composite properties based on a variety of applications. Polymers of the present disclosure display an exceptionally wide range of chemistries and physical properties. As such, the polymer may be selected to tailor the properties of the resultant composite. Adjustable curing times, temperatures, and physical properties of the resulting composite may be selected for a particular desired application. For example, the composite may be chosen to an appropriate hardness, or flexural or elastic moduli. Additionally, polymer systems tend to exhibit exceptional bond strength and low toxicity and volatility.

[0096] While the present disclosure has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments may be devised which do not depart from the scope of the present disclosure. Accordingly, the scope of the present disclosure should be limited only by the attached claims.

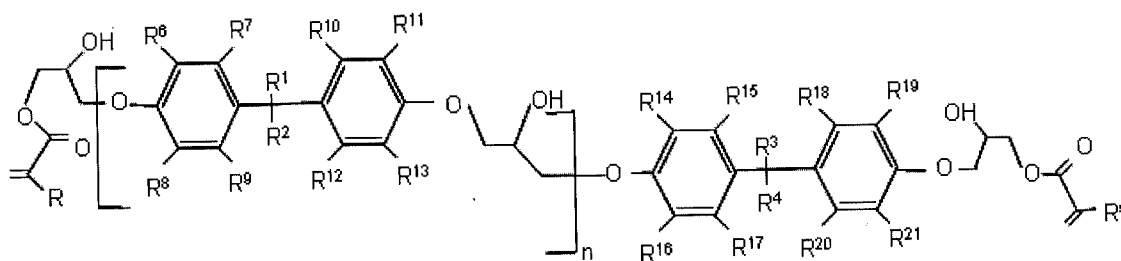
CLAIMS

What is claimed is:

1. A method of treating a wellbore, comprising:

emplacing in at least in an annular region formed between a wellbore wall and a casing or liner, a formulation comprising:

at least one polymer capable of polymerizing through a free radical polymerization reaction from the group of epoxy acrylates, modified epoxy acrylates, epoxy precursors, modified epoxy vinyl esters, unsaturated polyesters, urethane (meth)acrylates, polyester acrylates, epoxy vinyl ester resins having the formula:



wherein R and R¹ - R⁵ may be CH₃- or H and R⁶ - R²¹ may be H or Br,
and polymer combinations thereof; and

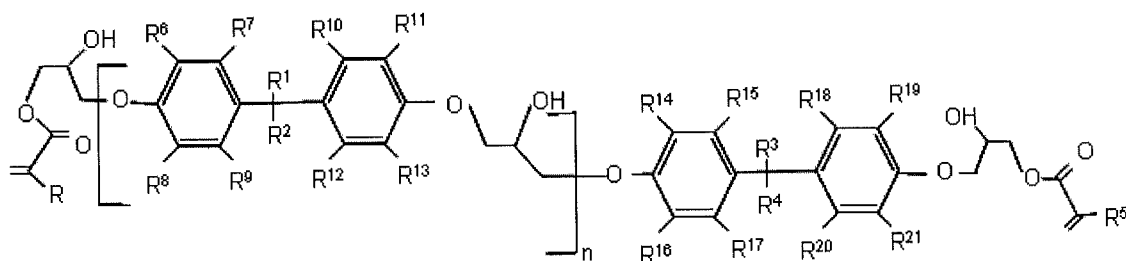
at least one initiator;

initiating polymerization of the at least one polymer to form a composite material in the annular region.

2. A method of treating a wellbore, comprising:

emplacing in at least in an annular region formed between a first casing string and a second casing string, a formulation comprising:

at least one polymer capable of polymerizing through a free radical polymerization reaction from the group of epoxy acrylates, modified epoxy acrylates, epoxy precursors, modified epoxy vinyl esters, unsaturated polyesters, urethane (meth)acrylates, polyester acrylates, epoxy vinyl ester resins having the formula:



wherein R and R¹ - R⁵ may be CH₃- or H and R⁶ - R²¹ may be H or Br,

and polymer combinations thereof; and

at least one initiator;

initiating polymerization of the at least one polymer to form a composite material in the annular region.

3. A method of treating a wellbore, comprising:

emplacing between a production tubing and a wellbore wall or casing string and

adjacent a mechanical packer, a formulation comprising:

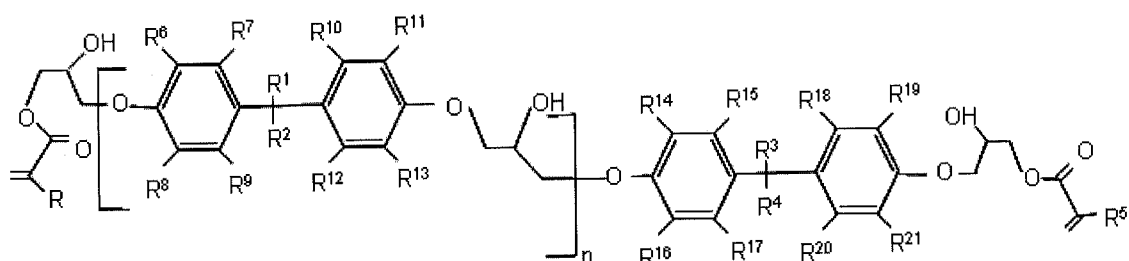
at least one polymer capable of polymerizing through a free radical

polymerization reaction from the group of epoxy acrylates, modified

epoxy acrylates, epoxy precursors, modified epoxy vinyl esters,

unsaturated polyesters, urethane (meth)acrylates, polyester acrylates,

epoxy vinyl ester resins having the formula:



wherein R and R¹ - R⁵ may be CH₃- or H and R⁶ - R²¹ may be H or Br,

and polymer combinations thereof; and

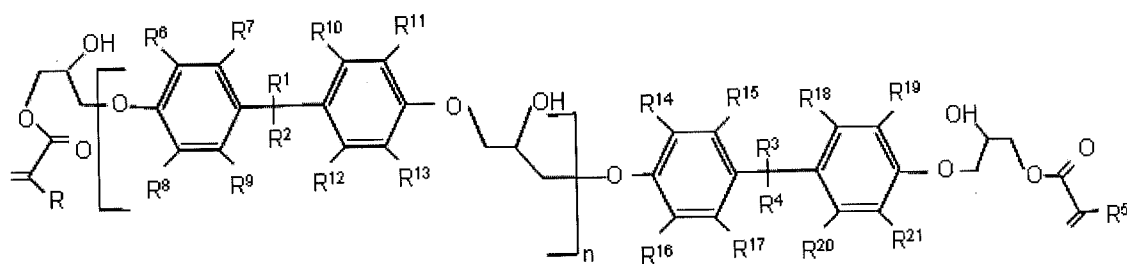
at least one initiator;

initiating polymerization of the at least one polymer to form a composite material in adjacent the mechanical packer.

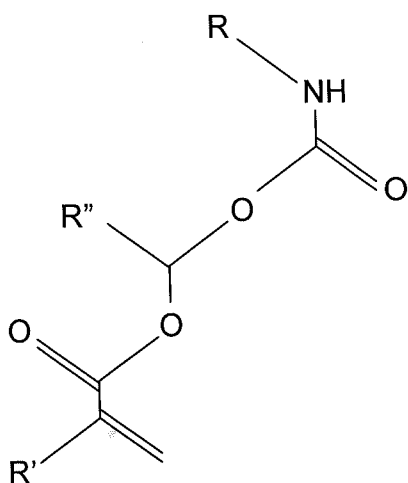
4. The method of any of the above claims, wherein the at least one polymer is present in the amount from about 10 to about 90 weight percent.

5. The method of any of the above claims, wherein the formulation further comprising at least one monomer from the group of vinyl monomers, acrylates, methacrylates, and vinyl ester monomers.
6. The method of claim 5, wherein the monomers are from the group of styrene, vinyl toluene, alpha methyl styrene, divinyl benzene, tertiary butyl styrene, diallyl phthalate, isocyanurate and combinations thereof.
7. The method of claim 5, wherein the monomers are from the group of monofunctional, multifunctional, hydroxyl functionalized, amine functionalized, carboxylic acid functional, polyether polyol extended, all esters of acrylic acid or methacrylic acid, and combinations thereof.
8. The method of claim 7, wherein the monomers are from the group of hydroxyethyl methacrylate (HEMA), hydroxypropyl methacrylate (HPMA), acrylic acid, methacrylic acid, methyl acrylate, ethyl acrylate, propyl acrylate, butyl acrylate, isodecyl acrylate, stearyl acrylate, lauryl acrylate, tridecyl acrylate, isoctyl acrylate, ethoxylated bisphenol A diacrylate, ethoxylated hydroxyethyl acrylate, allyl acrylate, glycidyl methacrylate, 1,4-butanediol diacrylate (BDDA), 1,6-hexanediol diacrylate (HDDA), diethylene glycol diacrylate, 1,3-butylene glycol diacrylate, neopentyl glycol diacrylate, cyclohexane dimethanol diacrylate, dipropylene glycol diacrylate, ethoxylated bisphenol A diacrylate, trimethylolpropane triacrylate, pentaerythritol triacrylate, pentaerythritol tetraacrylate, polyethylene glycol diacrylate, polypropylene glycol diacrylate, 4 - acryloylmorpholine, metal chelated derivatives of acrylates, related derivatives, methacrylate derivatives, acrylate derivatives, and combinations thereof.
9. The method of claim 5, wherein the vinyl ester monomers are esters of versatic acid.
10. The method of any of the above claims, wherein the formulation further comprises at least one weighting agent.
11. The method of any of the above claims, wherein the formulation further comprises at least one inhibitor.

12. The method of any of the above claims, wherein the initiator is selected from the group consisting of a free radical initiating catalyst, azo compounds, alkyl or acyl peroxides or hydroperoxides, dialkyl peroxides, ketoperoxides, peroxy esters, peroxy carbonates, peroxy ketals, and combinations thereof.
13. The method of claim 12 wherein the free radical initiating catalyst is selected from the group consisting of benzoyl peroxide, dibenzoyl peroxide, diacetyl peroxide, di-*t*-butyl peroxide, cumyl peroxide, dicumyl peroxide, dilauryl peroxide, *t*-butyl hydroperoxide, methyl ketone peroxide, acetylacetone peroxide, methylethyl ketone peroxide, dibutylperoxyl cyclohexane, di (2,4-dichlorobenzoyl) peroxide, diisobutyl peroxide, *t*-butyl perbenzoate, *t*-butyl peracetate, and combinations thereof.
14. The method of any of the above claims, wherein the at least one polymer is a mixture of an epoxy vinyl ester resins having the formula:



a urethane (meth)acrylate having the formula:



wherein R may be an aliphatic or aromatic, R' or R'' may be hydrogen or methyl

15. The method of any of the above claims wherein introducing the at least one polymer and introducing the at least one initiator into the earthen formation occurs simultaneously.
16. The method of any of the above claims wherein introducing the at least one polymer and introducing the at least one initiator into the earthen formation occurs sequentially.

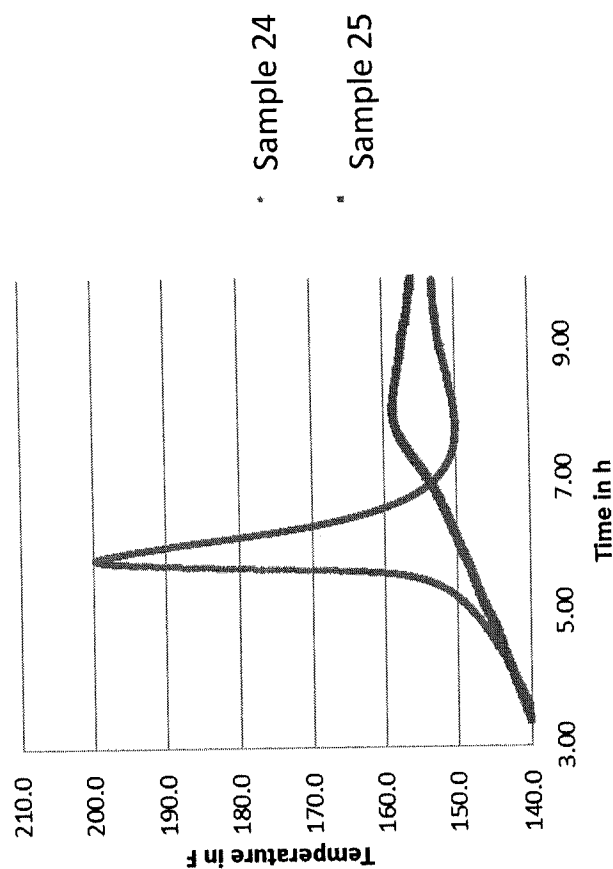


FIG. 1

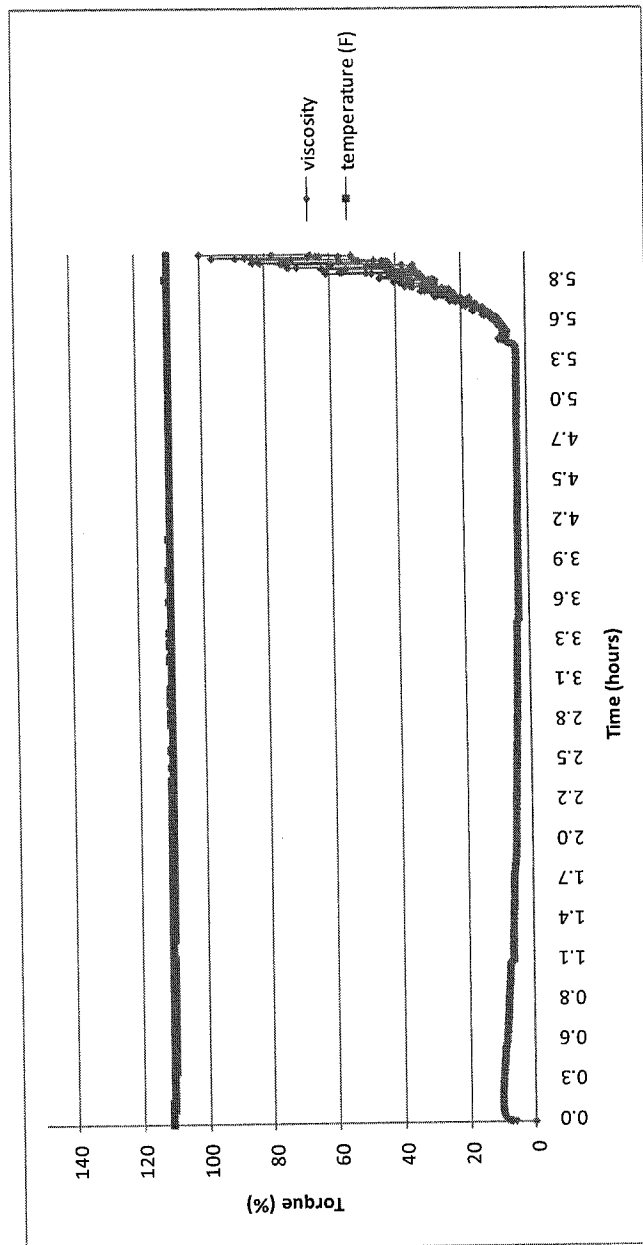


FIG. 2

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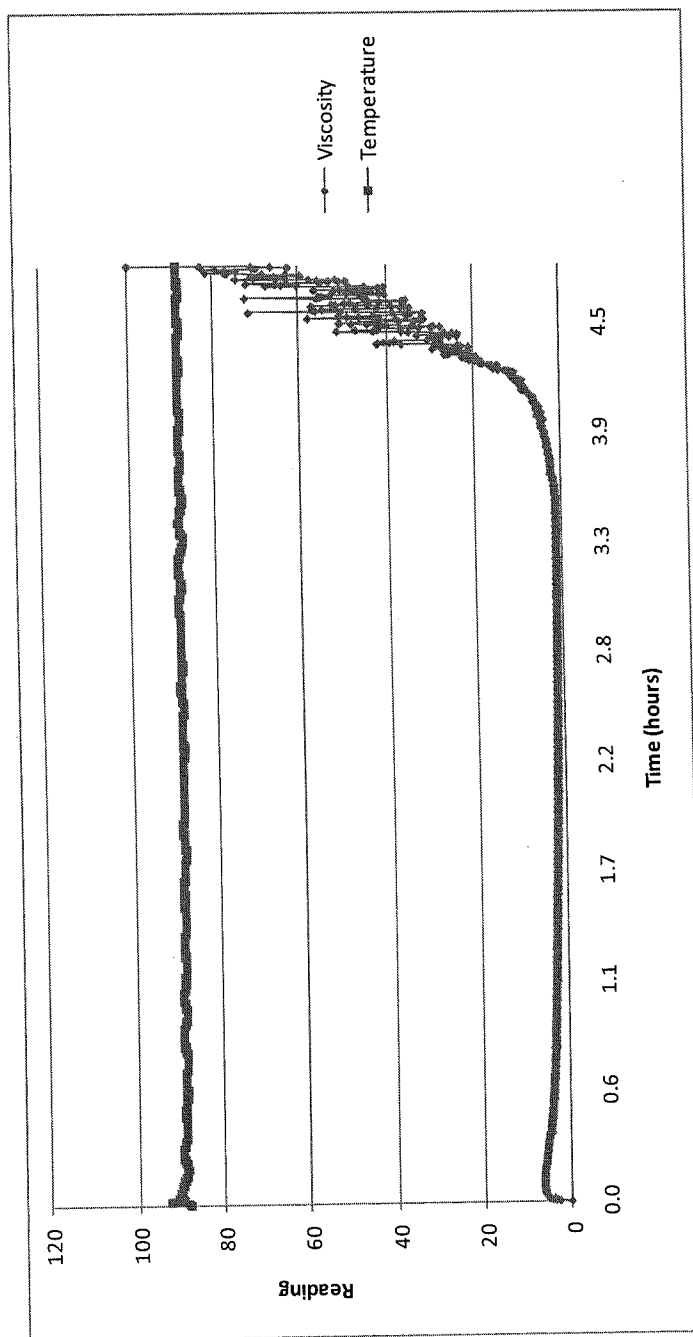


FIG. 3

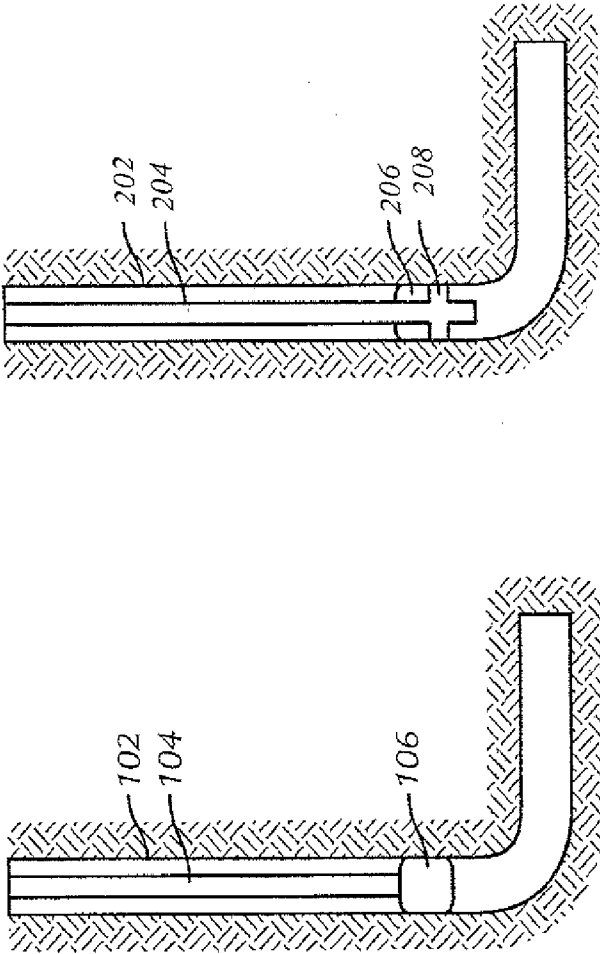


FIG. 4

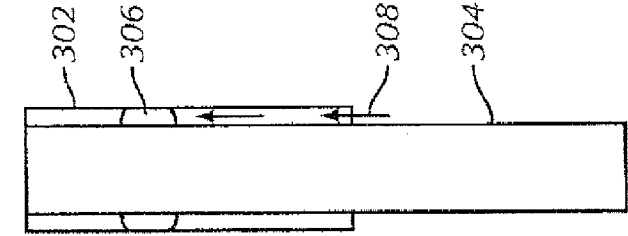


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/045920**A. CLASSIFICATION OF SUBJECT MATTER*****C09K 8/508(2006.01)i, C09K 8/512(2006.01)i***

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C09K 8/508; C08K 3/36; E21B 33/138; C08K 3/30; E21B 43/00; C08K 3/34; E21B 33/14; E21B 33/13; C09K 8/62; F16L 1/038; C09K 8/80; C09K 8/00; C08G 59/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: wellbore, epoxy vinyl ester resins, annular region, casing strings

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5875844 A (CHATTERJI, JITEN et al.) 02 March 1999 See abstract; column 1, lines 6-22; column 2, lines 46-52; column 3, lines 3-6; column 3, lines 47-53; column 4, lines 47-56; claims 1, 2 and 12.	1-4
X	US 2007-0227733 A1 (VERCAEMER, CLAUDE et al.) 04 October 2007 See abstract; paragraphs [0002], [0003] and [0014]-[0020]; claims 11 and 17.	1-4
X	US 6565285 B1 (LANDRICHTER, WOLFGANG) 20 May 2003 See abstract; column 1, lines 20-29; column 2, lines 4-7; column 3, lines 50-62; column 4, lines 9-24; figs. 1-3; claim 2.	1-4
A	WO 2011-042826 A2 (SCHLUMBERGER CANADA LIMITED) 14 April 2011 See abstract; paragraphs [0001], [0006], [0007], [0021], [0022], [0027], [0032], [0034], [0037] and [0038]; figs. 1, 2; claims 1, 18 and 19.	1-4
A	WO 2012-015860 A1 (3M INNOVATIVE PROPERTIES COMPANY) 02 February 2012 See abstract; page 1, lines 22-25; page 4, line 16 - page 5, line 30; and page 7, lines 1-12; claim 13.	1-4
A	US 6034155 A (ESPELAND, JOHN D. et al.) 07 March 2000 See abstract; column 7, line 1 - column 8, line 17; claims 1, 4 and 20.	1-4

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

25 MARCH 2013 (25.03.2013)

Date of mailing of the international search report

26 MARCH 2013 (26.03.2013)

Name and mailing address of the ISA/KR



Facsimile No. 82-42-472-7140

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2012/045920**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.: 6-9, 13
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

Claims 6, 7, 9 and 13 are in reference to multiple dependent claims 5 and 12, which is not subjected to meaningful search in accordance with the second and the third sentences of Rule 6.4(a).
And claim 8 is unclear because it refers to unclear dependent claim 7.
3. ☒ Claims Nos.: 5, 10-12, 14-16
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2012/045920

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2007-0021309 A1 (BICERANO, JOZEF) 25 January 2007 See abstract; paragraphs [0006], [0029], [0037], [0062] and [0063]; table. 2; claims 1, 4, 7 and 36.	1-4
A	US 4375489 A (MUSZYNSKI, LARRY C.) 01 March 1983 See abstract; column 1, lines 1-35, column 2, lines 25-35, column 4, lines 3-26 and column 8, lines 10-37; claims 1, 2 and 10-12.	1-4

INTERNATIONAL SEARCH REPORT

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International application No.

PCT/US2012/045920

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